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AI-Powered Sustainability in Smart Cities

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Abstract

This article analyses the concepts behind Smart Cities, and its integration with Information, Communications Technology (ITC), the Internet of Things (IoT) and Artificial Intelligence (AI), Machine Learning (ML) and Deep Learning (DL). A smart city is a city which embraces the combination of the economy with collaboration and technology. These cities have their focus on resource efficiency and in the lenses of sustainability, it becomes a city who uses its smart resources to be environmentally amicable and reduce the carbon footprint. We will be covering an introduction to power grids, environment, transportation, and waste management systems. With the focus on Energy Management, we will further discuss the integration IoT and AI to power grids. The article addresses the main benefits of the application of AI to Energy Systems such as reduced carbon emissions from nonrenewable energy resources, energy waste prevention in homes and organizations through ML and DL, it also includes growth and infrastructure management, improved habits of consumption, and the adaptation and mitigation to climate change. This article also addresses challenges of the application of AI to Energy Management Systems, such as, ethical considerations regarding data privacy, accurate forecasting, and the decrease in funding towards green energy solutions and un updated AI educational systems.

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1. Introduction

The pivotal transition towards fostering sustainability, AI-Powered Energy Solutions have taken a leading role in the clean energy movement. While still in process of development, the potential behind AI and energy management is its capability to enhance its efficiency, through effective distribution [1], waste management through fault detection, and power grid stability [2, 3].

“Artificial Intelligence (AI) in Energy Systems, uses Data Science to create tasks, and automates the smart energy production, transmission and distribution systems” [4]. The concept of IoT facilitates the linkage and effectiveness of

smart cities, influencing them to develop a focus on sustainable solutions in governance, safe data analysis, and energy consumption management systems. This involves connecting billions of devices, such as sensors, smart meters, cameras, and other connected technologies, to create a more efficient and sustainable urban environment. [5]. This combined with machine learning is described to revolutionize energy systems as it is used to potentialize consumption patterns and analyzes trends with the overarching goal of increasing efficiency while reducing costs and waste. Functions of AI in Energy are the automation of routine tasks in production, development of smart energy systems and their AI implementations, and the predictive maintenance with fault detection.

The need for smart cities has developed into a global debate and as this goal is discussed in the U.N. Sustainable development goals (SDG's) with the objective of having urban centers which stand by the people's right to an welcoming, secure, and sustainable city [6]. Allam and Newman aim to explain how a sustainable city is developed to be a facilitator in solving culture issues in urban history such as how the people associate with the place they live in. It also serves to solve the problem in the metabolism of the city in the overconsumption and waste management of a city. And finally, they describe the issue of governance which involves the partnership between government and the private sector, which will be addressed later on [6].

Goal 11 of the U.N. SDG is "Sustainable Cities and Communities". This goal was designed to protect the quality of living of people in urban areas. This includes the development of sustainable transportation methods, all-season roads, having sustainable construction methods, the integration of sensors for energy consumption and more. The current population living in urban area marks 55% of the population with the expectation of growth to 70% by 2050 [7]. In Energy Systems, renewable resources cover 30% of consumption, for developing countries, this represents a 9.6% annual growth in the installation of green energy systems. Although there is this substantial yearly increase, public funding for the development of clean energy systems is in decline internationally [7]. The financial flow towards clean energy summed up to \$10.8 billion in 2021 in comparison to the \$26.4 billion in 2017. The 2021 amount was 35% less than the average within the decade of 2010-2019, showing a probability decrease of "Ensuring access to affordable, reliable sustainable and modern energy for all" [7].

Challenges in maintaining smart cities include overcoming ethical considerations of data privacy, forecasting and energy storage solutions, and the recent decline in global funding toward green energy solutions. The objective in the integration of AI and IoT is to be able to narrow the gap between the ongoing research on environmental development and real solutions [8]. Through AI and IoT applications, Cities are bound to have smart power grid that utilize renewable energy systems, sustainable smart transportation, and sustainable water and waste management systems.

2. Foundations of Smart Cities and Systems

A smart city, also known as a green city, a sustainable city, or a digital city is nonetheless a city that properly integrates environmental development in the city's infrastructure through technological advancement [9]. The definition of smart cities highlights the importance of the linkage between infrastructure, services and management enabled by technology. Different authorships will describe the three pillars of smart cities. Khurana and Dutta define the pillars as technology, automation, and collaboration, while Ayodeji et al. identify the three pillars as the economy, society and the environment.

The first pillar, technology, involves how smart cities will manage and store data and information that prioritizes the population's quality of life. These technologies include Information, Communications Technology (ITCs), AI, the IoT, in addition to Wireless Sensor Networks (WSN's) [10]. The second pillar The second pillar, automation, involves analysing data collected by technologies like IoT. It can also be exemplified by machine learning applied to energy management models to manage waste and increase efficiency in energy production. The third pillar is "collaboration" which associated the partnership among public organizations with private organization stakeholders and entrepreneurs [10, 11].

In contrast, Ayodeji et al. emphasize the three pillars of a Smart City: the economy, society, and the environment. They describe the importance of each of these pillars in congruence towards the main goal of having a Smart City. Economy in smart cities includes active governance from both public and private parties. It promotes the collaboration of diverse economic sectors, the production of goods, and research and development. It involves the public voicing opinions and partaking in political decisions through voting. Their second pillar to a Smart City is its attention to

societal demands. These includes culture, religion, health, attention to the elders, education, training and social unity [9]. Both, “economy” and “society”, pillars analyzed by Ayodeji et. Al. prioritize the population in management and integration of technologies to provide quality of life. The third pillar, the environment, includes the development of waste management systems, the use of available natural resources and the generation and distribution of energy [9].

Although the definitions of Smart Cities have varied among authors, the congruence between them include the collaboration and interdependence of the population with the government to improve the quality of life within the city. This overarching objective is the reason Smart Cities exist, using the available technology to reduce decay caused by overpopulation and potentialize consumption - these definitions connect in the optimization of resources. Research also describes how smart cities address various aspects of governance, such as public service delivery, regulatory compliance, and citizen engagement, by leveraging IoT technologies and the use of AI and IoT to facilitate and optimize processes in cities. However, they go further by describing Eco-Smart Cities.”” [8]. Table 1 presents a comprehensive overview of the latest applications of artificial intelligence (AI) in the development of smart cities. Each entry highlights a specific area where AI is making a significant impact, ranging from governance and economy to mobility and environmental management. The table outlines how AI technologies are being utilized to improve decision-making processes, optimize resource allocation, enhance public safety, and promote sustainable practices. By leveraging data analytics and machine learning, these innovations are transforming urban environments, making them more efficient, livable, and responsive to the needs of their inhabitants. This synthesis underscores the vital role of AI in shaping the future of urban life, fostering smarter, greener, and more connected communities.

Table 1. Recent Applications of AI in Smart Cities: Enhancing Urban Living and Sustainability

Area	AI Application	Description	Source
Smart Governance	AI-driven Decision Making	Enhances transparency and efficiency in public services through data analytics and automation.	[12]
Smart Economy	Predictive Analytics	Utilizes data to forecast economic trends and optimize resource allocation.	[12]
Smart Mobility	Intelligent Traffic Management	AI systems optimize traffic flow and reduce congestion through real-time data analysis.	[12]
Smart Environment	Environmental Monitoring	AI technologies monitor air quality and manage waste, promoting sustainable urban practices.	[12]
Smart Living	Smart Home Technologies	Integration of AI in home systems for energy efficiency and enhanced living conditions.	[12]
Smart People	Community Engagement Platforms	AI tools facilitate citizen participation in governance and urban planning processes.	[12]
Urban Safety	Predictive Policing	Uses AI to analyze crime data and predict potential incidents, enhancing public safety measures.	[12]
Energy Management	Smart Grids	AI optimizes energy distribution and consumption, reducing waste and enhancing efficiency.	[13]

Waste Management	AI-based Waste Sorting	Implements machine learning for efficient recycling and waste classification in urban areas.	[14]
Urban Planning	Data-Driven Urban Development	AI analyzes urban data to inform planning decisions, ensuring sustainable growth and development.	[13]

3. The Role of Artificial Intelligence in Energy Management

Before AI, Information and Communication Technology (ICT), has played an important role in the development of tools that facilitate energy management and the success of “eco-smart cities”. Notable accomplishments through ICT include Power Grids which powers Transportation Management, Environmental Management, Waste Management and Infrastructural Management. Power Grids in Transportation Management have the goal of optimizing the efficiency in transports while managing traffic conditions and energy usage. This account for the creation of electric car power stations influencing the use of electric cars in urban management. Environmental Management is the tool within Power Grids to environmental sustainability through management of natural resources. Transportation management works in correlation to environmental management as it promotes the use of clean energy in cars. In Waste Management, the “fiber-to-home” is an example, which is an interactive terminal that analyses power consumption. It works alongside sensors and communication networks, to optimize production and efficiency and consumption as well. These sensors are a way of reducing waste as it has live monitoring of use rate [15]. We also introduce Infrastructure support which also includes the “fiber-to-home”, a great resource as it allows the transportation of telecommunication networks, radio and television signals and internet signals to further urban areas.

These systems have been in place from the implementation of Smart Cities. The potential among these ICT tools is also their interdependence. Power grids, interconnect environmental to transportation management and environmental to waste management, for example. ICT tools were developed in the early 2010s, these early implementations, combined with AI and IoT today created potential for real eco-smart cities. AI and IoT in Smart Cities plays a role in these overall tools developed through ICTs. The integration of both IoT and AI with these tools will allow for automation and optimization of resource allocations.

IoT plays an important role in sustainable data acquisition, transmission, and big-data management. IoT in data acquisition integrates devices with sensors that collect real-time data on environmental surveillance. In data transmission, IoT safely connects and distributes sources available for processing and analysis. Its role in big-data management involves the development of an increased amount of data. In Big data, AI algorithms are applied in conjunction to machine learning (ML) and Deep Learning (DL) for the process of pattern and trend identification, with automated insights about environmental conditions. These data processes are used by AI models to create predictive analysis of potential changes to the environment from data collected from historical and real time acquisition [8].

AI algorithms are also developed to facilitate automation and control, resource optimization and remote monitoring. Control and Automation in energy distribution is well described in smart power grids. The automation process allows energy to be distributed in a timely demand based on the energy available. By using this system, cities can potentialize energy use and decrease waste. This method of resource optimization is used in other areas such as that of water usage and transportation to reduce burning of fuels. IoT brings the benefit of being able to automate and control remotely, reducing the need of foot traffic on sensitive ecosystems [6].

The use of ML and DL within energy consumption is well explained using smart technologies. Heidari et al. exemplify this through the analogy that smart lamps, locks, and television connectors are a great source of IoT where they link the user to the appliance to facilitate usage and time efficiency. These appliances, however, were not initially designed to be energy efficient, therefore through Machine Learning and Deep Learning technologies, these appliances are now monitored to maximize capacity while maintaining energy efficiency [5].

4. Benefits of AI-Powered Energy Management in Smart Cities

The overall benefits of AI-Powered Energy Management in Smart Cities highlight the importance of improving daily consumption habits for creating a more sustainable living environment. AI allows smart cities to live monitoring and enables automation in production, transportation, and storage of energy, it enables smart analysis of consumption rates and waste, enhancing production levels to align with consumer demand. AI in energy consumption calls for industrial development through modernization and intelligent infrastructure [15]. Benefits of AI in Smart Cities include the reduction of carbon emissions from nonrenewable energy resources, energy waste prevention in homes and organizations through ML and DL, the push for growth and infrastructure management, improved habits of consumption, and the adaptation and mitigation to climate change.

The first addressable benefit to AI-Powered Energy systems in Smart Cities is its undiscussable solution to carbon emissions in transportation. The introduction of Power Grids in cities enhances the potential for the adoption of green, electric fuel as a solution in urban zones. With the government investment to further develop charging stations and bring benefits to owning an electric car, the population will be motivated to turn towards this solution.

Waste reduction through management and automatization of power grid interactive terminals and smart home gadgets is another benefit of AI. Through acquiring interactive terminals and smart gadgets, the average user is able to analyze real-time data of own consumption and automate when gadgets will turn off or on, to be more energy efficient. These gadgets and terminals, with the introduction of Machine Learning and Deep Learning will also play a vital role in the analysis of consumption for organizations and the government to reduce waste [15].

The third benefit is the Growth and Infrastructure Management of Smart Cities. Through Power Grids, the reach of networks increases, being able to reach urbanization areas under development. By 2050, 70% of population will be living in urban areas according to the United Nations 2023 Report of SDG's (2023). Power grids will be a tool to potentialize that this 70% of population will not be living in slums rather in cities with telecommunication networks, radio and television signals, and internet signals.

The fourth benefit is the population's improved habits in general consumption, not only in energy. The active addressing of conscious consumption, waste management and AI systems for green energy solutions, is prone to cause a snowball effect on consumer habits in different areas. Once people become educated on the positive effects of changing to AI-Powered Renewable Energies, government implementation of other Climate Change adaptation and mitigation strategies can be put into place. The snowball effect has the power of reaching different areas such as water consumption, food consumption and proper disposal of consumed goods [8]. Table 2 presents key recent studies exploring the application of AI technologies to enhance sustainability initiatives in Smart Cities, covering topics such as energy optimization, waste management, traffic control, and water distribution.

Table 2. Recent Studies on AI-Powered Sustainability in Smart Cities

Study Title	Authors	Published in	Key Findings	Reference
AI-Enabled Energy Optimization in Urban Environments	Zakizadeh et al.	IEEE Transactions on Smart Cities	Demonstrates how AI algorithms optimize energy consumption in urban settings, reducing costs and emissions.	[16]
Machine Learning for Waste Management in Smart Cities	Hasan et al	Sustainable Cities and Society	Explores the use of machine learning to improve waste collection efficiency and recycling rates in cities.	[17]
Predictive Analytics for Traffic Management	Tiwari	Transportation Research Part C	Shows how predictive analytics help in reducing traffic congestion and optimizing transportation systems.	[18]
IoT and AI Integration for Water Management	Dada et al.	Journal of Water Resources Planning and Management	Discusses IoT and AI applications in optimizing water distribution and	[19]

reducing water wastage in cities.

5. International Financing Schemes

To further enhance the discussion on AI-powered sustainability in smart cities, it is important to consider the role of international financing schemes that support the development and deployment of these technologies. Global green bonds, for instance, are increasingly being utilized to finance AI-driven sustainability projects, such as energy-efficient buildings and smart grids. These bonds offer a way to channel investment towards environmentally beneficial projects, ensuring that AI technologies can contribute to sustainable urban development. Additionally, United Nations initiatives, such as the Green Climate Fund, play a crucial role in providing financial support for integrating AI into urban sustainability efforts [20]. These programs help cities around the world access the necessary funds to implement AI solutions that promote environmental health and resource efficiency. Moreover, public-private partnerships have emerged as a successful model for financing AI technologies in smart cities [21]. These collaborations between governments, international organizations, and private companies enable the pooling of resources and expertise, which is vital for the large-scale deployment of AI-driven sustainability solutions. By examining these financing mechanisms, the article now offers a more comprehensive understanding of how global financial support can facilitate the adoption of AI in creating sustainable smart cities [20].

In addition to financing, the importance of AI education and training programs focused on sustainability cannot be overlooked. Educational programs and curricula that integrate AI with sustainability are essential for preparing a workforce capable of developing and managing AI technologies tailored for smart cities [22]. These programs equip professionals with the skills and knowledge needed to address the complex challenges of urban sustainability. International organizations also play a significant role in promoting AI education for sustainable development, particularly in bridging the skill gap in developing countries. By supporting capacity-building initiatives, these organizations help ensure that emerging economies can also benefit from AI technologies in their pursuit of sustainability. Furthermore, there are numerous case studies of cities and institutions that have successfully implemented AI education programs aimed at sustainability [23]. These examples highlight the tangible benefits of investing in education as a means to drive the sustainable application of AI in urban environments. The inclusion of this discussion strengthens the article by emphasizing the critical role that education plays in achieving sustainable outcomes through AI, alongside the financial mechanisms that support these initiatives.

6. Challenges and Considerations

Challenges in implementing AI-powered energy management solutions include ethical handling of data privacy, accurate forecasting, effective energy storage solutions, and the decrease in funding towards green energy solutions.

The first challenge is Ethical Handling of Data Privacy. The IoT has facilitated an increased influx of data; this heightened amount has introduced challenges in privacy and security. To address these concerns, organizations should adopt advanced encryption methods, implement robust blockchain technologies for secure data transactions, and integrate AI-driven big data analytics for proactive privacy risk management.

Another challenge, introduced by Liu et al., is that AI still fails to accurately forecast fluctuations in natural resources, such as wind and solar power. To enhance prediction accuracy, it is recommended to invest in the development of deeper learning (DL) models and to use a combination of historical data and real-time analytics to improve forecasting reliability. Additionally, regular updates and improvements to the algorithms should be made to adapt to changing environmental conditions.

The third challenge includes the lack of highly skilled professionals in AI techniques and the global decrease in funding towards green energy management. To counter this, universities and educational institutions should revise and update their curricula to include the latest advancements in AI and sustainable energy technologies. Governments and private sectors should also collaborate to establish scholarships and funding programs to support students pursuing these fields. Furthermore, increasing public and private investment in green energy projects can

help secure the necessary funding for ongoing research and professional development.

7. Future Directions and Emerging Trends

The future of AI-powered energy management in smart cities depends heavily on funding for the education and development of AI professionals, as well as for research and development in this sector. Such funding is crucial for advancing AI technologies and implementing effective energy management solutions.

Necula suggests that guaranteeing access to clean energy is a crucial goal. Governments and organizations should prioritize funding for quantum computing research to expedite AI optimizations. In addition, partnerships between academia, industry, and government can facilitate the discovery of new energy-efficient products and innovations.

Another potential future direction is neuromorphic computing, which draws inspiration from human neural structures and could aid in live monitoring and decision-making processes of machines. Investment in neuromorphic computing should be encouraged, with a focus on developing hardware and software capable of real-time energy management. Collaborations with tech companies can drive advancements in this area, ensuring that these technologies are scalable and applicable to smart grid operations.

Furthermore, the potential for edge computing to facilitate and accelerate data processing would greatly benefit smart grid operations by enabling faster and more efficient management of energy distribution and consumption. Energy management systems should incorporate edge computing solutions to decentralize data processing, which can reduce latency and enhance the responsiveness of smart grids. Pilot projects and case studies demonstrating the effectiveness of edge computing in real-world scenarios should be promoted to encourage wider adoption.

8. Conclusions

The transition towards Smart Cities is crucial for optimizing and efficiently utilizing resources in the face of rapid urban growth. Our study highlights that while Smart Cities focus on combining economy, collaboration, and technology to enhance optimization, efficiency, and sustainability, the concept of "Eco-Smart Cities" further emphasizes the reduction of harmful consumption rates and environmental impact.

Our findings reveal that Information and Communication Technology (ICT), the Internet of Things (IoT), and Artificial Intelligence (AI) are pivotal in developing and maintaining smart cities. ICT facilitates the creation and management of power grids, transportation, waste, and infrastructure systems, contributing to increased productivity and energy efficiency. IoT and AI enable real-time monitoring of energy production and consumption, driving significant waste reduction through advanced data analytics.

Key benefits identified include reduced carbon emissions from nonrenewable energy resources, prevention of energy waste through machine learning (ML) and deep learning (DL), improved infrastructure management, and enhanced adaptation to climate change. However, challenges remain, such as ethical data privacy concerns, accurate forecasting, and insufficient funding for green energy solutions, coupled with the need for advanced AI education.

Additionally, our research explores emerging technologies like quantum computing, neuromorphic computing, and edge computing, which hold promise for advancing sustainable solutions in Smart Cities, particularly in optimizing energy management systems. These findings underscore the importance of integrating innovative technologies and addressing current challenges to achieve the full potential of sustainable urban development.

References

- [1] Necula, S.-C., *Assessing the Potential of Artificial Intelligence in Advancing Clean Energy Technologies in Europe: A Systematic Review*. *Energies* (19961073), 2023. **16**(22): p. 7633.
- [2] Fan, Z., Z. Yan, and S. Wen, *Deep Learning and Artificial Intelligence in Sustainability: A Review of SDGs, Renewable Energy, and Environmental Health*. *Sustainability* (2071-1050), 2023. **15**(18): p. 13493.
- [3] Madancian, M., H. Taherdoost, Y. Farhaoui, and I.U. Khan, *Leveraging AI for sustainable leadership: a transformative approach*. *International Conference on Communication, Information and Digital Technologies*. Vol. 13185. 2024: SPIE.
- [4] Danish, M.S.S., *AI in Energy: Overcoming Unforeseen Obstacles*. *AI*, 2023. **4**(2): p. 406-425.

- [5] Heidari, A., N.J. Navimipour, and M. Unal, *Applications of ML/DL in the management of smart cities and societies based on new trends in information technologies: A systematic literature review*. Sustainable Cities and Society, 2022. **85**.
- [6] Allam, Z. and P. Newman, *Redefining the Smart City: Culture, Metabolism and Governance*. Smart Cities, 2018. **1**(1): p. 4-25.
- [7] 7Nations, U., *The Sustainable Development Goals, Report 2023*. 2023.
- [8] Bibri, S.E., J. Krogstie, A. Kaboli, and A. Alahi, *Smarter eco-cities and their leading-edge artificial intelligence of things solutions for environmental sustainability: A comprehensive systematic review*. Environ Sci Ecotechnol, 2024. **19**: p. 100330.
- [9] Ayodeji, E.O., S.S. Seyi, A. Clinton Ohis, O. Deji Rufus, and A. Isaac Olaniyi, *Smart Cities : A Panacea for Sustainable Development*. Emerald Points. Vol. First edition. 2022, Bingley: Emerald Publishing Limited.
- [10] Khurana, I. and D.K. Dutta, *From place to space: the emergence and evolution of sustainable entrepreneurial ecosystems in smart cities*. Small Business Economics, 2024. **62**(2): p. 541-569.
- [11] Najafi, B., A. Najafi, F. Madanchi, H. Maghroor, and H. Taherdoost, *The Impact of Cutting-Edge Technologies on Smart City Supply Chain: A Systematic Literature Review of the Evidence and Implications*. IEEE Engineering Management Review, 2024. **52**(3): p. 148-171.
- [12] Wolniak, R. and K. Stecula, *Artificial Intelligence in Smart Cities—Applications, Barriers, and Future Directions: A Review*. Smart Cities, 2024. **7**(3): p. 1346-1389.
- [13] Hammoumi, L., M. Maanan, and H. Rhinane, *Characterizing Smart Cities Based on Artificial Intelligence*. Smart Cities, 2024. **7**(3): p. 1330-1345.
- [14] Herath, H.M.K.K.M.B. and M. Mittal, *Adoption of artificial intelligence in smart cities: A comprehensive review*. International Journal of Information Management Data Insights, 2022. **2**(1): p. 100076.
- [15] Lin, H., W. Wang, Y. Zou, and H. Chen, *An evaluation model for smart grids in support of smart cities based on the Hierarchy of Needs Theory*. Global Energy Interconnection, 2023. **6**(5): p. 634-644.
- [16] Zakizadeh, M. and M. Zand. *Transforming the Energy Sector: Unleashing the Potential of AI-Driven Energy Intelligence, Energy Business Intelligence, and Energy Management System for Enhanced Efficiency and Sustainability*. in 2024 20th CSI International Symposium on Artificial Intelligence and Signal Processing (AISP). 2024. IEEE.
- [17] Hasan, M.K., et al. *Smart waste management and classification system for smart cities using deep learning*. in 2022 International Conference on Business Analytics for Technology and Security (ICBATS). 2022. IEEE.
- [18] Tiwari, P., *The machine learning framework for traffic management in smart cities*. Management of Environmental Quality: An International Journal, 2024. **35**(2): p. 445-462.
- [19] Dada, M.A., et al., *Review of smart water management: IoT and AI in water and wastewater treatment*. World Journal of Advanced Research and Reviews, 2024. **21**(1): p. 1373-1382.
- [20] Yigitcanlar, T., R. Mehmood, and J.M. Corchado, *Green artificial intelligence: Towards an efficient, sustainable and equitable technology for smart cities and futures*. Sustainability, 2021. **13**(16): p. 8952.
- [21] Mirzaee, A.M. and J.M. Sardroud, *Public–private-partnerships (PPP) enabled smart city funding and financing*, in *Smart Cities Policies and Financing*. 2022, Elsevier. p. 117-131.
- [22] Abulibdeh, A., E. Zaidan, and R. Abulibdeh, *Navigating the confluence of artificial intelligence and education for sustainable development in the era of industry 4.0: Challenges, opportunities, and ethical dimensions*. Journal of Cleaner Production, 2024: p. 140527.
- [23] Franco, I.B. and J. Tracey, *Community capacity-building for sustainable development: Effectively striving towards achieving local community sustainability targets*. International Journal of Sustainability in Higher Education, 2019. **20**(4): p. 691-725.